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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:	Confirmation No. 5493
Zheng Yuan et al.	Examiner: Kelly M. Stouffer
Application No.: 10/757,770	Technology Center/Art Unit: 1792
Filed: January 14, 2004	APPELLANTS' BRIEF UNDER 37 CFR §41.37
For: LIMITED THERMAL BUDGET FORMATION OF PMD LAYERS	

Mail Stop Appeal Brief
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

Further to the Notice of Appeal mailed on January 22, 2008 for the above-referenced application, Appellants submit this Brief on Appeal.

1. REAL PARTY IN INTEREST

Applied Materials, Inc. is the real party in interest as the assignee of the above-identified application.

2. RELATED APPEALS AND INTERFERENCES

No other appeals or interferences are known that will directly affect, are directly affected by, or have a bearing on the Board decision in this appeal.

3. STATUS OF CLAIMS

All pending claims 1-28 stand rejected pursuant to the Final Office Action mailed August 21, 2007.

The rejection of each of these claims are believed to be improper and is the subject of this appeal.

4. STATUS OF AMENDMENTS

No claim amendments have been filed subsequent to the mailing of the Final Office Action of August 21, 2007. A Response to this Final Office Action, which did not include a claim amendment, was mailed October 22, 2007. The Response prompted an Advisory Action mailed October 26, 2007, in which the claim rejections from the August 21 Final Office Action were maintained.

5. SUMMARY OF CLAIMED SUBJECT MATTER

In the following summary, Appellants have provided exemplary references to sections of the specifications and drawings supporting the subject matter defined in the claims as required by 37 C.F.R. § 41.37. The specification and drawings also include additional support for other exemplary embodiments encompassed by the claimed subject matter. Thus, these references are only intended to be illustrative and not restrictive.

Shrinking circuit elements on semiconductor devices has produced tall and narrow gaps that are difficult to fill with dielectric material. Conventional filling techniques designed to fill a gap quickly at a constant deposition rate often sealed off the top of the trench too early—a problem called "pinch off"—forming a void in the middle of the gap. In some chips, the void could be closed by reflowing the dielectric in a subsequent annealing step. However, more advanced chips use materials like nickel silicide that lower the thermal budget below the reflow temperature of many undoped and even doped dielectric materials.

Without an easy method to close voids, new deposition techniques were needed that prevented the voids from forming in the first place. One technique was to reduce the deposition rate to give the depositing dielectric material more time to distribute along the bottom and sides of the gap. However, a reduced deposition rate meant longer deposition times and

reduced productivity for the fabrication equipment. Embodiments of the present invention address this problem by varying a ratio of silicon and oxidizing processing gases while forming a conformal layer in the gap. Varying this ratio also varies the deposition rate to create a layer that stays conformal with the walls of the gap, but takes less time than a conformal layer formed at a constant deposition rate. When doped dielectic layers such as P-doped silicate glass are used, embodiments of the invention also include varying a ratio of phosphorous-containing gas during the deposition.

Independent claim 1

Claim 1 is directed to a method of filling a gap defined by adjacent raised features on a substrate (*see, e.g.*, structure 200 in Fig. 2, and p. 2, ll. 19-20). The method includes providing a flow of a silicon-containing processing gas to a chamber housing the substrate (*see, e.g.*, step 406 in Fig. 4, and p. 2, ll. 20-21). Providing a flow of an oxidizing processing gas to the chamber (*see, e.g.*, step 408 in Fig. 4, and p. 2, ll. 21-22). Providing a flow of a phosphorous-containing gas to the chamber (*see, e.g.*, step 410 in Fig. 4, and p. 2, ll. 22-23). Depositing a first portion of the P-doped silicon oxide film as a substantially conformal layer in the gap by causing a reaction between the silicon-containing processing gas, the phosphorous-containing processing gas, and the oxidizing processing gas (*see, e.g.*, p, 2, ll. 23-26). Where deposing the conformal layer comprises varying between a beginning and end of the depositing the conformal layer a ratio of the (silicon-containing processing gas plus phosphorous-containing processing gas):(oxidizing processing gas) (*see, e.g.,* step 412 in Fig. 4, and p. 2, ll. 26-28). And maintaining the temperature of the substrate below about 500°C throughout deposition of the conformal layer (*see, e.g.*, step 414 in Fig. 4, and p. 2, ll. 28-29).

The method further includes thereafter depositing a second portion of the P-doped silicon oxide film as a bulk layer (*see, e.g.,* part 404 in Fig. 4, and p. 2, ll. 29-30). Depositing the second portion of the film comprises maintaining the ratio of the (silicon-containing processing gas plus phosphorous-containing processing gas):(oxidizing processing gas) substantially constant throughout deposition of the bulk layer (*see, e.g.,* p. 2, ll. 30-32). And maintaining the

temperature of the substrate below about 500°C throughout deposition of the bulk layer (*see, e.g.*, step 422 in Fig. 4, and p. 3, ll. 1-2).

Independent claim 5

Claim 5 is directed to a method of filling a gap defined by adjacent raised features on a substrate (*see, e.g.*, structure 200 in Fig. 2, and p. 2, ll. 19-20). The method includes providing a flow of a silicon-containing processing gas to a chamber housing the substrate (*see, e.g.*, step 306 in Fig. 3, and p. 2, ll. 20-21). Providing a flow of an oxidizing processing gas to the chamber (*see, e.g.*, step 308 in Fig. 3, and p. 2, ll. 21-22). Depositing a first portion of a silicon oxide film as a substantially conformal layer in the gap by causing a reaction between the silicon-containing processing gas and the oxidizing processing gas (*see, e.g.*, part 302 in Fig. 3, and p. 3, ll. 10-12). Where depositing the conformal layer comprises varying between a beginning and end of the depositing of the conformal layer a ratio of the (silicon-containing processing gas):(oxidizing processing gas) (*see, e.g.*, step 310 in Fig. 3, and p. 12-13). And maintaining the temperature of the substrate below about 500°C throughout deposition of the conformal layer (*see, e.g.*, step 312 in Fig. 3, and p. 3, ll. 20-21).

The method further includes thereafter depositing a second portion of the P-doped silicon oxide film as a bulk layer (*see, e.g.*, part 304 in Fig. 3, and p. 3, ll. 16-17). Where depositing the second portion of the film comprises maintaining the ratio of the (silicon-containing processing gas):(oxidizing processing gas) substantially constant throughout deposition of the bulk layer (*see, e.g.*, p. 3, ll. 17-19). And maintaining the temperature of the substrate below about 500°C throughout deposition of the bulk layer (*see, e.g.*, step 320 in Fig. 3, and p. 3, ll. 19-20).

The method additionally includes thereafter depositing a cap layer comprising a P-doped silicon oxide film while maintaining the substrate below about 500°C throughout deposition of the cap layer (*see, e.g.*, p. 3, ll. 20-22).

Independent claim 8

Claim 8 is directed to a method of processing a semiconductor substrate (*see, e.g.*, p. 3, ll. 23-24). The method includes providing a flow of a silicon-containing process gas to a

chamber housing the substrate (*see, e.g.*, p. 2, ll. 24-25), and providing a flow of an oxidizer gas to the chamber (*see, e.g.*, p. 2, ll. 25-26). A reaction is caused between the silicon-containing process gas and the oxidizing process gas to form a silicon oxide layer on the substrate (*see, e.g.*, p. 2, ll. 26-27). A ratio of the (silicon-containing gas):(oxidizing gas) flowed into the chamber is varied over time to alter a rate of deposition of the silicon oxide on the substrate between a beginning and end of the deposition of a substantially conformal layer (*see, e.g.*, p. 2, ll. 27-29). Throughout processing of the semiconductor substrate, the substrate is maintained at or below a reflow temperature of the silicon oxide layer (*see, e.g.*, p. 3, ll. 30-31).

Independent claim 19

Claim 19 is directed to a method of processing a semiconductor substrate (*see, e.g.*, p. 4, ll. 14-15). The method includes providing a flow of a silicon-containing process gas to a chamber housing the substrate (*see, e.g.*, step 406 in Fig. 4, and p. 4, ll. 15-16). Providing a flow of an oxidizing process gas to the chamber (*see, e.g.*, step 408 in Fig. 4, and p. 4, l. 16). Providing a flow of a phosphorous-containing process gas to the chamber (*see, e.g.*, step 410 in Fig. 4, and p. 4, ll. 16-17). A reaction is caused between the silicon-containing process gas, the oxidizing process gas, and the phosphorous-containing gas to form a P-doped silicon oxide layer on the substrate (*see, e.g.*, p. 4, ll. 17-19). A ratio of the (silicon-containing gas):(oxidizing gas):(phosphorous-containing gas) flowed into the chamber is varied over time to alter a rate of deposition of the silicon oxide on the substrate between a beginning and end of the deposition of a substantially conformal layer (*see, e.g.*, step 412 in Fig. 4, and p. 4, ll. 19-22).

6. GROUNDS OF REJECTION TO BE REVIEWED ON APPEAL

The grounds of rejection to be reviewed on appeal are:

1. The rejection of claims 1, 5, 8-11, 13-14, 19-22, and 24 under 35 U.S.C. § 103(a) over *Xia et al* (U.S. Pat. No. 6,218,268);
2. The rejection of claims 15-18 and 25-28 under 35 U.S.C. § 103(a) over *Xia* in view of *Vassilev et al* (U.S. Pat. No. 6,500,771);
3. The rejection of claims 2, 3, 6, and 7 under 35 U.S.C. § 103(a) over *Xia* in view of *M'Saad* (U.S. Pat. No. 6,013,584); and

4. The rejection of claims 4, 12, and 23 under 35 U.S.C. § 103(a) over *Xia* in view of *Jeng* (U.S. Pat. Pub. No. 2002/0050605).

7. ARGUMENT

For purposes of this appeal, claims 2-4, 5-6, 9-18, and 20-28 may stand or fall with respect to independent claims 1, 5, 8, and 19, respectively. No admission is made by the grouping of the claims.

A. Rejection of claims 1, 5, 8-11, 13-14, 19-22, and 24 under 35 U.S.C. § 103(a) over *Xia*

Claims 1, 5, 8-11, 13-14, 19-22, and 24 are rejected as obvious over *Xia*. The Office concedes *Xia* does not describe varying, between the beginning and end of the deposition of a conformal layer, a ratio of two precursors used to deposit the layer. However, the Office asserts that *Xia's* description of a two-step deposition process where the ratio of precursors are different, but constant, in each deposition step renders obvious varying the ratio within a step. The Applicants respectfully disagree, viewing *Xia's* two-step deposition process being closer to the deposition of two separate layers than a single layer made by continuously varying a ratio of precursors. Moreover, *Xia* warns that a dopant-deficient layer can form when the silicon precursor is changed too quickly, reducing the reflow properties of the layer. If anything, this warning teaches away from varying the ratio of precursors during the deposition of a dielectric layer. For at least these reasons, the claims are not obvious over *Xia*.

The element of varying, between the beginning and end of the deposition of a conformal layer, a ratio of two precursors used to deposit the layer, is described in all four independent claims: Claim 1 describes "varying between a beginning and end of the depositing of the conformal layer a ratio of the (silicon-containing processing gas plus phosphorous-containing processing gas):(oxidizing processing gas)." Claim 5 recites "varying between a beginning and end of the depositing of the conformal layer a ratio of the (silicon-containing processing gas):(oxidizing processing gas)." Claim 8 notes "varying over time a ratio of the (silicon-containing gas):(oxidizing gas) flowed into the chamber." Finally, Claim 19 states

"varying over time a ratio of the (silicon-containing gas):(oxidizing gas):(phosphorous-containing gas) flowed into the chamber."

As noted above, the Office concedes that *Xia* does not describe varying the ratio of deposition precursors between the beginning and end of a deposition:

> "Xia et al. does not explicitly include varying the ratios of gases between the beginning and end of the depositing of the conformal layer."
> (Office Action of August 21, 2007, p. 3, ll. 17-18).

However, the Office asserts that *Xia* suggests this element because the reference describes a two-layer deposition as improving gap filling, thickness uniformity, and film stability over a one-layer film. The Office argues that one of skill in the art reading this would "find it within their known options to use a graded dopant concentration to receive the above benefits, knowing that if two layers with two dopant concentrations improved over one layer it follows that one would want a layer made up of many dopant concentrations to improve over two dopant concentrations." (Office Action, p. 4, 17-21). On the contrary, one of skill in the art reading the entire reference would, if anything, find that it teaches away from using a graded dopant concentration.

Xia expressly notes that depositing a two-layer BPSG film with different deposition conditions between the layers is not simply a matter of changing the conditions. There were particular problems maintaining the relative phosphorous dopant concentration as the TEOS flow rate was changed. If the relative concentrations are not carefully controlled, a dopant deficiently layer can form that reduces re-flow and the ability to fill voids:

> It was discovered that depositing a two-layer BPSG film at different deposition conditions is not a matter of simply changing the conditions. A smooth transition between the first deposition conditions and the second deposition conditions is important to ensure a film with the desired properties, and especially to maintain the re-flow characteristics of the film. The re-flow characteristics of a BPSG layer depend on the dopant concentration, a higher dopant concentration typically resulting in better re-flow characteristics, such as a lower melting point and greater fluidity. A particular problem arose in maintaining the relative phosphorous dopant concentration as the TEOS flow rate was changed.
> .

> [A] dopant deficient layer in the middle of the BPSG layer reduces re-flow, and hence the ability to fill voids.
> (*Xia*, col. 13, l. 59 to col. 14, l. 15.)

If anything, this description teaches away from continuously varying precursor flow rates because it would be difficult to control the dopant concentration, increasing the chances of forming a dopant deficient layer. Thus, Xia does not suggest to one of skill in the art to use a continuously graded dopant concentration during the deposition of a conformal layer.

In a subsequent Advisory Action, the Office asserted that *Xia* did not teach away from continuously varying a precursor flow rate because the reference went on to describe a method to correct the problem of dopant deficiency (Advisory Action of October 26, 2007, p. 2, 1st Paragraph). However, the described solution was a mechanism that allowed a dopant and silicon-containing gas precursor stream to stabilize at an equilibrium concentration before being introduced into the deposition chamber (Xia, col. 14, ll. 24-29). While disconnecting precursor streams from the deposition chamber to let them stabilize may offer a solution for depositing two discrete dielectric layers, it is not a solution for continuously varying the precursor concentration during the deposition of a single layer. This solution to the problem of maintaining a relative phosphorous dopant concentration as the TEOS flow rate is changed would not work for methods of varying the precursor concentration during the deposition of a single layer. Thus, the reference still teaches away from varying precursor flow rate during single layer deposition.

For at least these reasons Claims 1, 5, 8, and 19 (and their dependent claims) are allowable over *Xia* and withdrawal of the rejection of Claims 1, 5, 8-11, 13-14, 19-22 and 24 under § 103(a) over the reference is respectfully requested.

B. Rejection of claims 15-18 and 25-28 under 35 U.S.C. § 103(a) over *Xia* in view of *Vassilev*

Claims 15-18 and 25-28 are rejected as obvious over *Xia* in view of *Vassilev*. This rejection is respectfully traversed for at least the reasons described above. *Xia* neither describes nor suggests varying, between the beginning and end of the deposition of a conformal layer, a ratio of two precursors used to deposit the layer, as described in claims 8 and 19 (and

therefore dependent claims 15-18 and 25-28). *Vassilev* does not remedy this deficiency in *Xia*, so claims 15-18 and 25-28 are allowable over the combination of references, and withdrawal of the rejection is respectfully requested.

C. Rejection of claims 2, 3, 6, and 7 under 35 U.S.C. § 103(a) over *Xia* in view of *M'Saad*

Claims 2, 3, 6 and 7 are rejected as obvious over *Xia* in view of *M'Saad*. This rejection is respectfully traversed for at least the reasons described above. *Xia* neither describes nor suggests varying, between the beginning and end of the deposition of a conformal layer, a ratio of two precursors used to deposit the layer, as described in claims 1 and 5 (and therefore dependent claims 2, 3, 6, and 7). *M'Saad* does not remedy this deficiency in *Xia*, so claims 2, 3, 6, and 7 are allowable over the combination of references, and withdrawal of the rejection is respectfully requested.

D. Rejection of claims 4, 12, and 23 under 35 U.S.C. § 103(a) over *Xia* in view of *Jeng*

Claims 4, 12, and 23 are rejected as obvious over *Xia* in view of *Jeng*. This rejection is respectfully traversed for at least the reasons described above. *Xia* neither describes nor suggests varying, between the beginning and end of the deposition of a conformal layer, a ratio of two precursors used to deposit the layer, as described in claims 1, 8 and 19 (and therefore dependent claims 4, 12, and 23). *Jeng* does not remedy this deficiency in *Xia*, so claims 4, 12, and 23 are allowable over the combination of references, and withdrawal of the rejection is respectfully requested.

8. CONCLUSION

For these reasons, it is respectfully submitted that the rejection should be reversed.

Respectfully submitted,

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9. CLAIMS APPENDIX

1. (Previously presented) A method of filling a gap defined by adjacent raised features on a substrate, comprising:

providing a flow of a silicon-containing processing gas to a chamber housing the substrate;

providing a flow of an oxidizing processing gas to the chamber;

providing a flow of a phosphorous-containing processing gas to the chamber;

depositing a first portion of a P-doped silicon oxide film as a substantially conformal layer in the gap by causing a reaction between the silicon-containing processing gas, the phosphorous-containing processing gas, and the oxidizing processing gas, wherein depositing the conformal layer comprises varying between a beginning and end of the depositing of the conformal layer a ratio of the (silicon-containing processing gas plus phosphorous-containing processing gas):(oxidizing processing gas) and maintaining the temperature of the substrate below about 500°C throughout deposition of the conformal layer; and

thereafter, depositing a second portion of the P-doped silicon oxide film as a bulk layer, wherein depositing a second portion of the film comprises maintaining the ratio of the (silicon-containing processing gas plus phosphorous-containing processing gas):(oxidizing processing gas) substantially constant throughout deposition of the bulk layer and maintaining the temperature of the substrate below about 500°C throughout deposition of the bulk layer.

2. (Original) The method of claim 1, further comprising:

thereafter, patterning metal lines on the substrate over the P-doped silicon oxide film; and

maintaining the temperature of the substrate below a reflow temperature of the P-doped silicon oxide film from a point in time immediately after deposition of the bulk layer to a point in time after patterning metal lines on the substrate.

3. (Original) The method of claim 2, wherein maintaining the temperature of the substrate below a reflow temperature of the P-doped silicon oxide film from a point in time immediately after deposition of the bulk layer to a point in time after patterning metal lines on the substrate comprises not annealing any portion of the substrate.

4. (Original) The method of claim 1, wherein the substrate comprises nickel silicide connectors and the P-doped silicon oxide film comprises a pre-metal dielectric layer.

5. (Previously presented) A method of filling a gap defined by adjacent raised features on a substrate, comprising:

providing a flow of a silicon-containing processing gas to a chamber housing the substrate;

providing a flow of an oxidizing processing gas to the chamber;

depositing a first portion of a silicon oxide film as a substantially conformal layer in the gap by causing a reaction between the silicon-containing processing gas and the oxidizing processing gas, wherein depositing the conformal layer comprises varying between a beginning and end of the depositing of the conformal layer a ratio of the (silicon-containing processing gas):(oxidizing processing gas) and maintaining the temperature of the substrate below about 500°C throughout deposition of the conformal layer;

thereafter, depositing a second portion of the silicon oxide film as a bulk layer, wherein depositing a second portion of the film comprises maintaining the ratio of the (silicon-containing processing gas):(oxidizing processing gas) substantially constant throughout

deposition of the bulk layer and maintaining the temperature of the substrate below about 500°C throughout deposition of the bulk layer; and

thereafter, depositing a cap layer comprising a P-doped silicon oxide film while maintaining the substrate below about 500°C throughout deposition of the cap layer.

6. (Original) The method of claim 5, further comprising:

thereafter, patterning metal lines on the substrate over the P-doped silicon oxide film; and

maintaining the temperature of the substrate below a reflow temperature of either the silicon oxide film or the P-doped silicon oxide film from a point in time immediately after deposition of the bulk layer to a point in time after patterning metal lines on the substrate.

7. (Original) The method of claim 6, wherein maintaining the temperature of the substrate below a reflow temperature of either the silicon oxide film or the P-doped silicon oxide film from a point in time immediately after deposition of the bulk layer to a point in time after patterning metal lines on the substrate comprises not annealing any portion of the substrate.

8. (Previously presented) A method of processing a semiconductor substrate, comprising:

providing a flow of a silicon-containing process gas to a chamber housing the substrate;

providing a flow of an oxidizer process gas to the chamber;

causing a reaction between the silicon-containing process gas and the oxidizing process gas to form a silicon oxide layer on the substrate;

varying over time a ratio of the (silicon-containing gas):(oxidizing gas) flowed into the chamber to alter a rate of deposition of the silicon oxide on the substrate between a beginning and end of the deposition of a substantially conformal layer; and

maintaining the substrate at or below a reflow temperature of the silicon oxide layer throughout processing of the semiconductor substrate.

9. (Original) The method of claim 8, wherein maintaining the substrate at or below a reflow temperature of the silicon oxide layer throughout processing of the semiconductor substrate comprises not annealing the substrate.

10. (Original) The method of claim 8, wherein the silicon oxide layer comprises a pre-metal dielectric layer.

11. (Original) The method of claim 8, wherein the substrate comprises a gap between adjacent surfaces, and wherein the silicon oxide is deposited in the gap.

12. (Original) The method of claim 8, wherein the substrate comprises nickel silicide.

13. (Original) The method of claim 8, further comprising providing a flow of a phosphorous-containing process gas to the chamber during a time period, wherein the flow of silicon-containing process gas is provided at least partly during the time period.

14. (Previously Presented) The method of claim 13, wherein the silicon-containing process gas comprises TEOS and wherein the phosphorous-containing process gas comprises TEPO.

15. (Original) The method of claim 13, further comprising:

thereafter providing a subsequent flow of phosphorous-containing process gas to the chamber.

16. (Original) The method of claim 15, further comprising, while providing the subsequent flow of phosphorous-containing process gas to the chamber, regulating a pressure of the chamber to a pressure in a range from about 200 torr to about 760 torr.

17. (Original) The method of claim 15, further comprising, while providing the subsequent flow of phosphorous-containing process gas to the chamber, forming a plasma from the phosphorous-containing process gas.

18. (Original) The method of claim 17, wherein the plasma has a density greater than about 1011 ions/cm3.

19. (Previously presented) A method of processing a semiconductor substrate, comprising:

providing a flow of a silicon-containing process gas to a chamber housing the substrate;

providing a flow of an oxidizing process gas to the chamber;

providing a flow of a phosphorous-containing process gas to the chamber;

causing a reaction between the silicon-containing process gas, the oxidizing process gas, and the phosphorous-containing gas to form a P-doped silicon oxide layer on the substrate; and

varying over time a ratio of the (silicon-containing gas):(oxidizing gas):(phosphorous-containing gas) flowed into the chamber to alter a rate of deposition of the silicon oxide on the substrate between a beginning and end of the deposition of a substantially conformal layer.

20. (Original) The method of claim 19, further comprising maintaining the substrate at or below at reflow temperature of the P-doped silicon oxide layer.

21. (Original) The method of claim 19, wherein the substrate comprises a gap between adjacent surfaces, and wherein the silicon oxide is deposited in the gap.

22. (Original) The method of claim 19, wherein the P-doped silicon oxide layer comprises a pre-metal dielectric layer.

23. (Original) The method of claim 19, wherein the substrate comprises nickel silicide.

24. (Previously Presented) The method of claim 19, wherein the silicon-containing process gas comprises TEOS and wherein the phosphorous-containing process gas comprises TEPO.

25. (Original) The method of claim 24, further comprising:

thereafter providing a subsequent flow of phosphorous-containing process gas to the chamber.

26. (Original) The method of claim 25, further comprising, while providing the subsequent flow of phosphorous-containing process gas to the chamber, regulating a pressure of the chamber to a pressure in a range from about 200 torr to about 760 torr.

27. (Original) The method of claim 25, further comprising, while providing the subsequent flow of phosphorous-containing process gas to the chamber, forming a plasma from the phosphorous-containing process gas.

28. (Original) The method of claim 27, wherein the plasma has a density greater than about 10^{11} ions/cm^3.

10. EVIDENCE APPENDIX

NONE

11. RELATED PROCEEDINGS APPENDIX

NONE